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DYNAMIC RELATIONS AND TERMINOLOGY OF STRATIGRAPHIC CONFORMITY AND UNCONFORMITY[1]

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GENERAL DEFINITIONS

Next in dynamic and structural importance to the stratification of sedimentary rocks are the relations of the strata designated by the terms conformity and unconformity. Most briefly defined, and with emphasis laid, as it should be, upon the dynamic aspect of the phenomena, conformity means that the process of deposition was not, and unconformity that it was, interrupted by erosion.

In other words, conformity implies that deposition was essentially continuous, that no true hiatus and consequently no period of erosion (the antithesis of deposition) intervened during the deposition of the series of which this structure is predicated. This definition, it will be noted, tacitly assumes that deposition does not fail absolutely from mere lack of material, where other conditions are favorable, although over extensive areas, including especially the abyssal depths of the ocean, it may be almost infinitely slow, long periods of geologic time being, for the particular region, virtually, though not absolutely, unrecorded; but such an apparent or even actual gap in a sedimentary series is consistent with perfect conformity, for the one absolute essential of a conformable series is that it be in no part a record of erosion.

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[1] In the preparation of this paper the author has had the advantage of discussing the subject with those two accomplished stratigraphers, Dr. A. W. Grabau and Dr. H. W. Shimer; and their helpful criticism and suggestions are gratefully acknowledged.

Unconformity, on the other hand, implies a true hiatus, an actual interruption of deposition by erosion, followed by further deposition. The erosion may be terrestrial (peneplanation) or littoral (marine planation). But it is necessary to emphasize the importance of the time break in order to exclude from consideration the localized erosion, both terrestrial and marine, due to shifting and variable currents and often closely accompanying deposition in both space and time. This phenomenon, known as contemporaneous erosion and deposition, giving rise locally, in one and the same sedimentary series, to numberless examples of the appearance, but never the reality, of true stratigraphic unconformity, is best relegated, with cross-bedding or current lamination, to the category of the irregularities of stratification. The one is not true unconformity any more than the other is true delta structure. The paramount, the vital or dynamic, interest of unconformity is found in the clear and unquestionable proof which it affords of a double interchange of land and sea, or at least of wide or general areas of erosion and of deposition. An important time break or hiatus is a necessary implication; and thus arises, somewhat incidentally, the great value of unconformity in stratigraphic demarkation and classification.

In order to avoid other possible misconceptions, it is needful, also, that attention be directed particularly to the fact that both conformity and unconformity are absolutely definite structures, definite in the sense that each is always sharply localized stratigraphically and may be predicated of a particular stratigraphic plane or contact. In other words, the student may put his finger on a definite line and say, "Here is conformity" or "Here is unconformity," as the case may be. This point is, perhaps, clearest for unconformity; but it must be obvious, on reflection, that conformity does not require that the top and bottom of a series should be parallel. Conformity exists throughout if at each line of stratification the structure is sensibly parallel and the deposition essentially continuous, continuity of deposition alone constituting conformity, and of this continuity parallel lamination is a common but by no means a necessary or infallible sign.

Again, these mutually exclusive structures are universal in the sense that the strata are everywhere either conformable or unconformable. And since true unconformity is absolutely inconsistent with continuous deposition, no mere irregularity of deposition, no matter how marked, can give rise to an unconformity. In general confirmation of this we have the fact that, so far as clearly recognized, each type of irregularity has, as we have seen, a designation of its own. In a later paragraph, additional names will be proposed for phases of conformity not always sharply distinguished from unconformity.

SEDIMENTARY PROVINCES

A. CONTINENTAL
  a) Terrestrial[1] (continental surface)
    The deposition may be:
      1. Eolian
      2. Fluvial
      3. Lacustrine
      4. Glacial
  b) Coastal (continental margin)
    The deposition may be:
      1. Estuarine and deltal
      2. Littoral (shore)
      3. Marine (continental platform)

B. OCEANIC (ABYSSAL DEPTHS)

An exhaustive scheme is not aimed at here; but the purpose is, rather, to set forth the commanding importance, as a theater of sedimentation, of the coastal zone or province. Erosion is the normal geologic activity of the terrestrial province; and terrestrial deposits, although in part widespread, are, nevertheless, characteristic of but a small fraction of the land surface, and are likely, except, in general, under graben conditions (localized depressions), to be relatively thin. They are also, in large part, transitory, being ultimately (perhaps during subsidence) reworked and deposited in the coastal province. Also, the oceanic or truly abyssal deposits, although of relatively limitless area, are especially noteworthy for their thinness and their wonderful uniformity over wide expanses.

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[1] The growing tendency to designate land deposits as terrestrial instead of continental meets the writer's approval. Terrestrial is clearly the more accurately descriptive term, since it does not exclude insular deposits, and does not include the deposits of the continental platform, which are as truly continental as any.

The coastal zone or province, although the narrowest, is, then, as every student knows, the specially important field of relatively permanent sedimentation. In other words, the old, broad generalization still holds, that sediments are derived from the land and deposited in the sea, and chiefly in the marginal portion of the sea; although the finer part of the terrigenous (non-cosmic) detritus may reach the abyssal or truly oceanic depths. The calcareous and siliceous oozes characteristic of the deep sea are, it may be observed in passing, truly land-derived, although the material is transported in solution and deposited by organic agency.

Again, in the terrestrial province the sediments are during their deposition almost constantly exposed to erosion. Contemporaneous erosion and deposition is peculiarly characteristic of this province, and the frequent occurrence of the resultant pseudo-unconformity tends to make the recognition of true or significant unconformity difficult. In the oceanic province, on the other hand, uniformity and conformity reign supreme and unconformity is virtually wanting. But in the coastal province the migrations of the shore are extremely favorable to the alternation of deposition and erosion over extensive areas and the development of true or normal unconformity.

The grand result of sedimentary activity in the coastal province is the building of the broad bench or terrace fringing the continent, of which the dry, landward portion is known as the coastal plain and the wet, seaward portion as the continental platform; and nowhere, probably, has the coastal province a more normal development than on the Atlantic and Gulf borders of North America.

THE COASTAL PLAIN OF EASTERN NORTH AMERICA[1]

The coastal province includes, as we have seen, the coastal plain and the continental platform. Concerning the geologic history and structure of the former our knowledge is fairly full and accurate and it is becoming more so with every new boring and excavation; while our knowledge of the latter is, and apparently must remain, largely conjectural or, more accurately, inferential, consisting of more or less valid deductions from what is known of the coastal plain. Hence it is natural that attention should now be concentrated upon the latter, although it is much the smaller part of the province. It is, however, the landward part and therefore the part that has been most affected by changes of level and consequent migrations of the shore; and it is for this reason, especially, much the more promising part as a field for the study of unconformity. A brief outline of the geologic history of the coastal plain will serve to bring into view the general relations of the strata which are the main objective of this paper, relations which are believed to hold for coastal plains generally, throughout the world and throughout geologic history.

During Jurassic time, what is now the Atlantic seaboard of the United States was elevated and suffering erosion; and on the complex geologic structure handed down from Paleozoic and older and from Triassic times was developed the so-called Cretaceous peneplain. This peneplained surface of the older formations is the true foundation or bed-rock of coastal plain geology—the floor and primary datum plane of coastal plain stratigraphy.

The subsequent history of the seaboard is comprised in an oscillatory and possibly isostatic seaward tilting of the Cretaceous peneplain, attended landward by erosion, resulting, during periods of relative stability, in the partial development of successively lower base-levels; and attended seaward by more or less continuous deposition and the development of the entire coastal plain series of Cretaceous and later sediments. This general crustal movement—depression seaward and elevation landward—has continued until the originally nearly level bed-rock surface (the Cretaceous peneplain) now slopes seaward beneath the coastal plain 75 to 100 feet per mile. Upon this sloping peneplain the coastal plain, which is continued seaward in the continental platform, holds the relation of a built terrace—thinning landward and thickening seaward.

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[1] This paper is one of the fruits of a somewhat elaborate study of coastal plain geology made under the auspices of the Board of Water Supply of New York City, with special reference to the geologic relations of the ground-water of Long Island. This investigation will, in due course, be published in full as a bulletin of the New York Geological Survey.

The oscillatory character of the movement has determined repeated seaward and landward migrations of the shore, with the result that within what may be called the axial zone of the seaboard or landward margin of the coastal plain, deposition and erosion alternated and stratigraphic conformity has been interrupted by unconformity; while seaward throughout a large part of the coastal plain and the whole of the continental platform, deposition has been relatively uninterrupted and conformable; and landward beyond the limits of the coastal plain, erosion has similarly prevailed.

Obviously these conditions are likely to continue until the distant future time when the increasing burden of unconsolidated sediments, accompanied by a gradual rise of the isogeotherms, has induced softening of the sub-crust or true bed-rock, and plication, with consequent crustal thickening and uplift, ensues. Thus when the revolution is complete and the land is again base-leveled by erosion, the way will have been prepared for another widespread or universal unconformity and the beginning of another grand cycle of deposition, leading to the development of a new continental platform and coastal plain.

UNCONFORMITY IN THE COASTAL PROVINCE

No attempt at a complete enumeration of the unconformities of the coastal plain (the accessible part of the coastal province) above the Cretaceous peneplain—the universal and absolute unconformity which forms its floor—is likely to be successful, except locally, for the simple reason that the crustal oscillations in which the unconformities have their origin have not affected uniformly all parts of the seaboard. The oscillations are known to have varied greatly longitudinally or in the trend of the coast; and transversely their differential effect must have been most marked because of the normal seaward tilt, increasing downward, of the coastal plain formations. The major divisions of these formations may be correlated with the major oscillations of the crust; and the principal unconformities are, therefore, interformational; while relatively local and subordinate unconformities may be described as intraformational or, better, as marking off, or giving distinctness to, the minor divisions of the geologic record.

The main point demanding attention now, however, is the striking contrast of all these coastal plain unconformities, both inter- and intraformational, to the great unconformity of the Cretaceous peneplain, forming the floor of the entire coastal plain series and recording a hiatus and a stratigraphic break of the first magnitude. This basal unconformity of the coastal plain is characterized by the profound deformation (plication, faulting, etc.) and metamorphism as well as by the extensive erosion of the diverse bed-rock formations before the deposition over them of the coastal plain series began. In other words, this unconformity is the joint product of deformation and erosion, while all the unconformities, both major and minor, actually within the coastal plain series are characterized by erosion alone, and exhibit no sensible deformation of the older before the deposition of the newer formations. In the one case the beds are discordant, and in the other case they are accordant in dip and strike.

TERMINOLOGY OF UNCONFORMITY

Grabau,[1] recognizing the numerous examples of accordant unconformity in the geologic record and the desirability of a distinctive name, has proposed for them the designation *disconformity*, reserving *unconformity* for the discordant type. This use of the prefix *dis-* is clearly unfortunate, since it implies a divergent and not a parallel relation of the strata. It is, moreover, desirable that we should have a generic term, applicable to all cases of a lack of conformity; and for this purpose *unconformity* has the sanction of usage and etymology. Unconformity should not, therefore, be restricted to a particular type of stratigraphic break, even though that one be the most important.

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[1] A. W. Grabau, *Science* (N.S.), XX, 534.

My first thought was to propose for the two types of unconformity—the parallel and divergent—the prefixes *para-* and *dis-*, respectively, thus matching the distinction in physics of paramagnetism and diamagnetism. But the prior use of *dis-* in the contrary sense has seemed to preclude, or at least to render undesirable, its use in this new, though etymologically more correct, sense. I therefore propose, instead, the prefixes *para-* and *clino-*. The terms may be written in full, and with a hyphen to aid pronunciation, thus, para-unconformity and clino-unconformity; or they may be abbreviated to parunconformity and clinunconformity.

Although these terms are, and, for the sake of convenience in designating and describing the phenomena, ought to be, structural, it is important, nevertheless, to recognize that the real, the fundamental, distinction, is dynamic; and of course the student should not be misled by the fact that a clinunconformity may locally show a parallel relation of the strata. The full significance of the distinction for which these terms stand is realized only in the broad view. We then see that parunconformities must be relatively frequent and local, recording the minor vertical oscillations of coastal plains undergoing progressive and, possibly, isostatic settling; while clinunconformities are few and widespread, recording the great crustal revolutions accompanied by profound readjustment and interchange of land and sea.

CONFORMITY IN THE COASTAL PROVINCE

Deposition within the coastal province is limited by two planes diverging seaward: (1) the level surface of the sea, the elevation of which is constantly shifting, with a general tendency to rise relatively to the land; (2) the sloping bed-rock surface, the buried Cretaceous peneplain. It is a significant fact that if the Cretaceous peneplain be projected seaward under the continental platform with its proved gradient beneath the coastal plain, it will be found at the foot of the continental slope approximately continuous with the floor of the abyssal ocean. We cannot doubt, therefore, in view of the shallow soundings of the continental platform, that the sediments of the coastal province, resting upon the Cretaceous peneplain, thicken enormously seaward. This has been abundantly confirmed by borings for individual members of the coastal plain series. Thus the Miocene formation, hardly a hundred feet thick near the landward edge of the coastal plain in the vicinity of the Delaware River, is more than a thousand feet thick at Atlantic City. The idea that sediments are necessarily thickest where they are coarsest must be reversed for the coastal province; and we must recognize the essentially wedgelike character of the formations of this province in directions normal to the coast.

The upper and lower members of the entire coastal series are strongly, and the upper and lower strata of one and the same member are distinctly, divergent seaward and convergent landward. Apparently, then, this sphenoidal tendency may be set down as the dominant and specially characteristic structural feature of the province; and yet, where subaerial erosion has not intervened, conformity prevails throughout; for the successive beds are everywhere conformable, the cumulative lack of parallelism becoming appreciable only when a notable thickness of sediments has been traversed.

TERMINOLOGY OF CONFORMITY

For the wedgelike type of conformity which we have seen to be specially characteristic of the coastal province, *sphenoconformity* appears to be an appropriate name; and for a correlative term, applicable wherever the strata are approximately uniform in thickness and sensibly parallel throughout, or in the general view, *planoconformity* is suggested. Planoconformity may obtain locally on the continental platform, but must be regarded as specially characteristic of the abyssal ocean floor.

It is an interesting question as to the effect upon the conformity of strata of contemporaneous deformation. If the deformation take the form of a general tilting, sphenoconformity will naturally result, as we have seen. And plication, conceding the possibility of its surface manifestation, would, apparently, yield only a more localized sphenoconformity. Contemporaneous faulting, on the other hand, suggests *fractoconformity*, although it is doubtful if the resultant structure would be markedly different from sphenoconformity; and essentially the same may be said for graben deposits.

GENERAL CONCLUSIONS

The Atlantic and Gulf coastal plain of the United States is believed to be a normal example of the coastal plains of the globe, and to be representative of the conditions under which, chiefly, sedimentary rocks have been formed in the past. The contact of the coastal plain sediments with the ancient floor or bed-rock surface on which they were deposited is everywhere the true and strongly marked clinunconformity of the Cretaceous peneplain. Above this peneplained floor, the coastal plain sediments are divided, landward, by repeated parunconformities developed during its progressive, oscillatory subsidence; while seaward they are apparently characterized through their entire thickness by the uninterrupted sphenoconformity indicative of continuous sedimentation, increasing in amount seaward or away from the source of the sediments owing to the constantly increasing divergence in that direction of its limiting planes—the Cretaceous peneplain and the surface of the sea.

When the coastal plain shall have been completed and its sediments, through the agency of deformation and metamorphism, shall have been added to the rigid crust these original structures will still persist. This entire body of post-Triassic sediments will be seen to be sharply limited downward by a strongly marked clinunconformity. Its original landward margin will be divided, as now, into a succession of terranes by an almost indefinite sequence of parunconformities, each the record of a complete crustal oscillation devoid of deformation; while throughout its more seaward portion, now largely embraced in the continental platform, the stratigrapher will be baffled by a blending sphenoconformity and a general absence of sharply defined stratigraphic boundaries.

NOTE.—Since this paper was written, my attention has been called to Arnold Heim's Monograph on "Die Nummuliten- und Flysch-bildungen der Schweizeralpen" (*Abhandlungen der schweizerischen paleontologischen Gesellschaft*, XXXV (1908), 173, in which he makes approximately, but not exactly, the same distinction between divergent and parallel uncomformity that is proposed here, by introducing the term *Paenaccordanz* (penaccordance). His scheme thus includes:

Accordanz = conformity (strata parallel).
Discordanz = unconformity (strata divergent) = clinunconformity.
Paenaccordanz = approximate conformity (strata nearly parallel) = parunconformity.

Paenaccordanz is not, however, a perfect equivalent of parunconformity. It suggests a structural gradation, which, of course, actually exists; but it fails to emphasize the vital contrast between unconformity due to crustal deformation and unconformity due to crustal oscillation.